PRINCESS CRUISES
escape completely

January 15, 2010

Denise Koch, Cruise Ship Program Manager
Commercial Passenger Vessel Environmental Compliance Program
Alaska Department of Environmental Conservation
410 Willoughby Avenue, Suite 303
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RE: Update – Interim Source Reduction Evaluation Report

Dear Denise:

As per Section 1.9 of the Large Commercial Passenger Vessel Wastewater Discharge Permit number 2007DB0002, please find Princess Cruises' progress report of its Source Reduction Evaluation efforts.

Princess Cruises would like to update ADEC of the progress from its trial onboard Golden Princess. The following two objectives will be explained in this update:

1. Observation of the nitrification process during MBR plant start-up;
2. The improvement of the nitrification efficiency by enhancing the MBR operational system parameters.

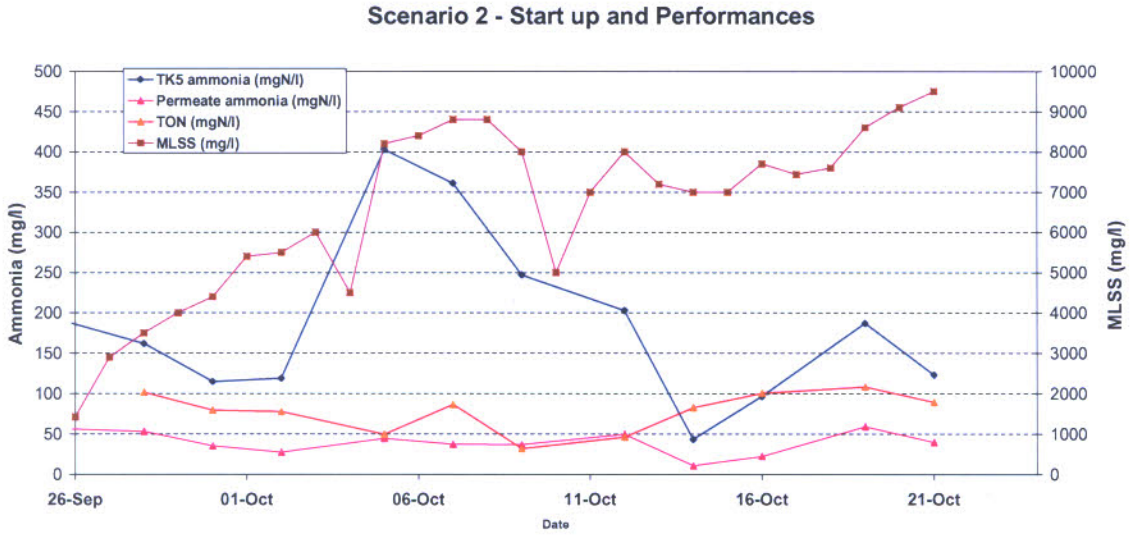
It has been concluded that the nitrification process starts-up and establishes very quickly when the Membrane Bio-Reactor (MBR) plant is seeded from another MBR plant. Approximately seventy-to-ninety percent of the ammonia removal has been achieved, although the ammonia level is not yet close to the General Permit long-term limit. The nitrification efficiency failed to improve by further prolonging the biomass age, increasing the dissolved oxygen and reducing the plant capacity. It is suspected that the efficiency may also be affected by a) high temperature unique to shipboard applications, and/or b) high ammonia fluctuations; and/or c) high ammonia concentration in the wastewater feed.

The trial further indicated that the fluctuation of ammonia loading to MBR plant No. 3 remains very significant and difficult to stabilize. The denitrification efficiency deteriorated during the trial period, possibly due to a malfunction of mixing blower. Due to a blockage of anoxic zone mixing pipe, maintenance work was required which involved shutting down of MBR No. 3. This part of the trial allowed the ship to utilize the situation positively, to observe a start-up process, by seeding MBR No. 3 using biomass from another operating MBR.

In order to further improve the nitrification efficiency, the following conditions were recommended by Hamworthy:

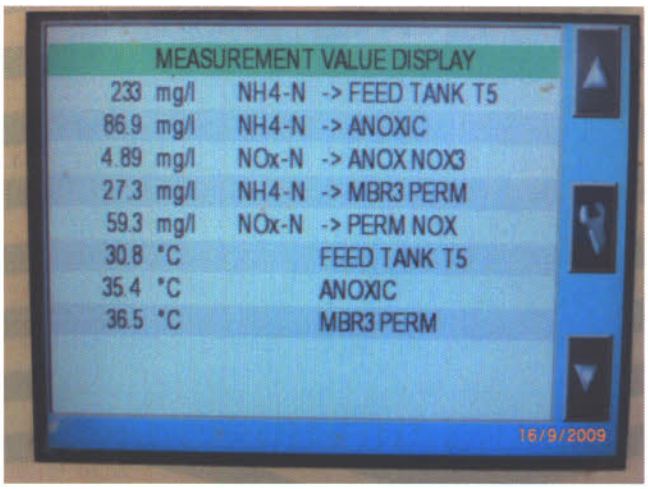
1) Both the Anoxic and Swing zones shall remain anoxic;
2) Increase and stabilize DO to 2.0 mg/l in the aerobic reactor (stage 2 reactor);
3) Reduce MBR feed to 90 m3/d;
4) Maintain grey:black mixing ratio of 2:1;
5) Extend the sludge age to 40 days – by desludge 3% daily.

It was observed that the nitrification process established almost immediately, with seeded biomass from another duty MBR (Graph 1). It is known that MBR 1 and 2 have partial nitrification, and the biomass would contain nitrifers. Nevertheless, it is useful to note that nitrification proceeded well at a much lower MLSS concentration during the start up period.



Graph 1. Process start-up when seeded from another duty MBR

New Computer Measurement System



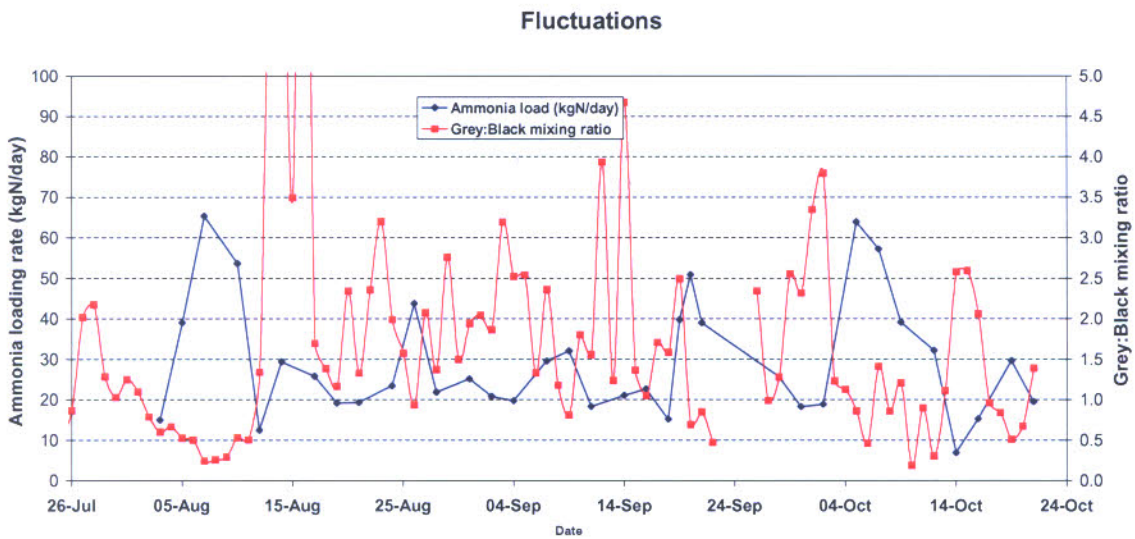
New Measurement Data Readings

Fluctuations

Through out the trial, it was observed that a significant amount of fluctuation of ammonia concentration and loading rate (Graph 2 and 3) occurred. It was difficult to stabilize the grey:black mixing ratio despite much efforts by ship staffs and Hamworthy engineers.

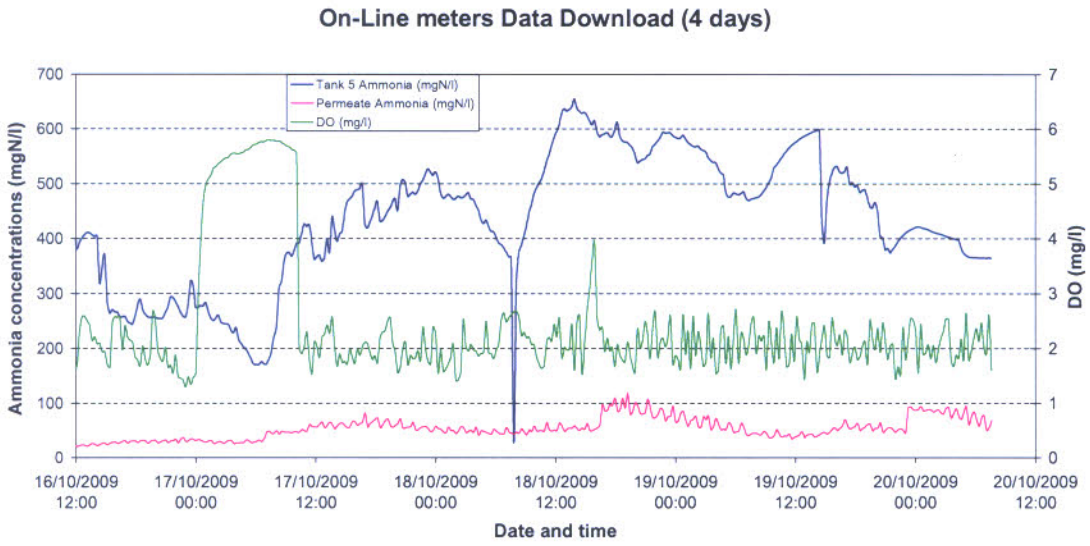
The graphs show the ammonia concentrations and loading rates fluctuated from day to day to a factor of over 3, as well as within a 24-hour period.

Considering the extreme differences in black and grey water characteristic, it can be concluded that the significant fluctuation is a condition unique to shipboard applications. A larger mixing/balancing tank may be essential for a ship application, performing the function of an equivalent municipal sewerage system. Although such mixing tank will not compensate the effect of a) very concentrated black water and b) sudden changes of grey water streams associated with various shipboard activities that are unseen in a municipal sewage treatment work.



Graph 2. Fluctuations of grey:black mixing ratio, and the ammonia loading rate to MBR no.3

Ship Equipment Used to Measure Ammonia

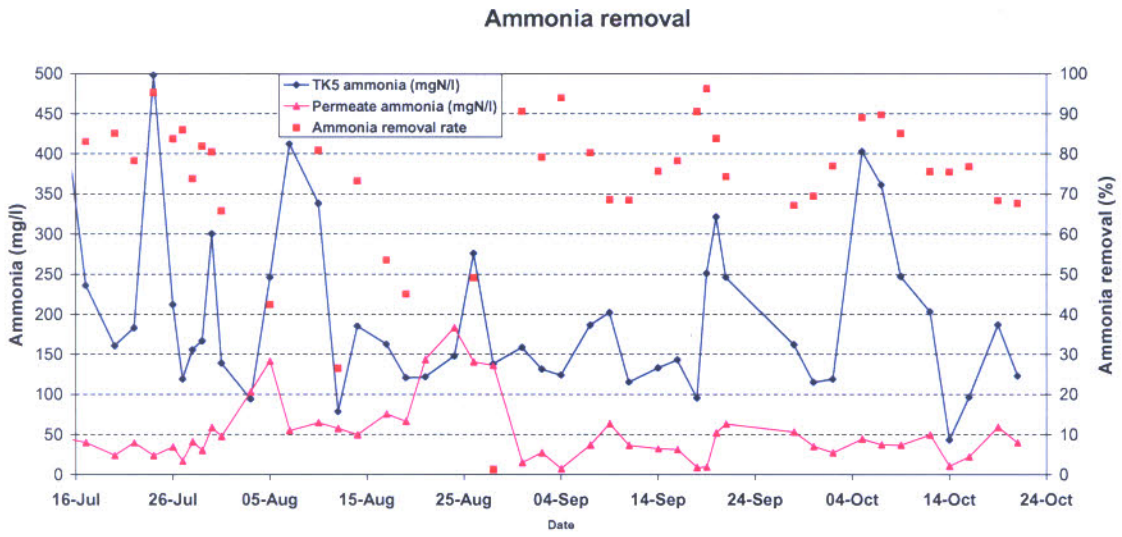


Graph 3. Diurnal fluctuations (date download from on-line instruments)

1) Nitrification efficiencies

Despite the following efforts on improving the operation parameters to improve the nitrification efficiency the results did not significantly improved (Graph 4).

- prolonging the sludge age,
- increasing the DO, and
- reducing the plant capacity,

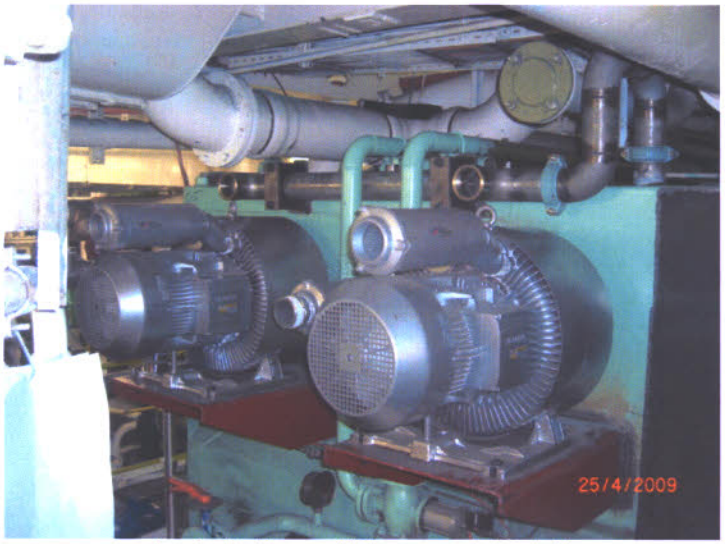


Graph 4. Nitrification removal performance

2) Denitrification performance

As shown in graph 1, there is a significant level of total oxidized nitrogen (TON) in the permeate, of which, nitrite consists of a major portion. This is unique, as in most of the municipal applications, nitrite level is insignificant comparing to nitrate in the treated wastewater. The build-up of nitrite could be due to high temperature or other inhibitive conditions.

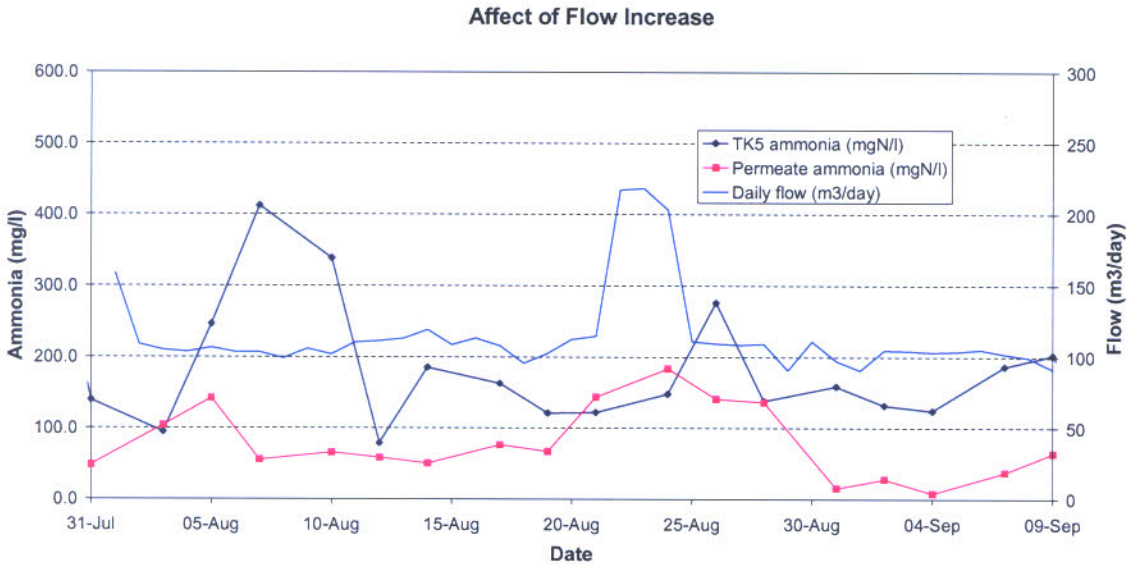
The mixing blower for Tank 5 was in continuous running for an unknown period. As a result, aerobic degradation occurred in Tank 5. Such condition deprived the anoxic zone of available carbon required for denitrification. This could be another reason why denitrification has not been as effective as expected.



Installation of Blowers Tank 5

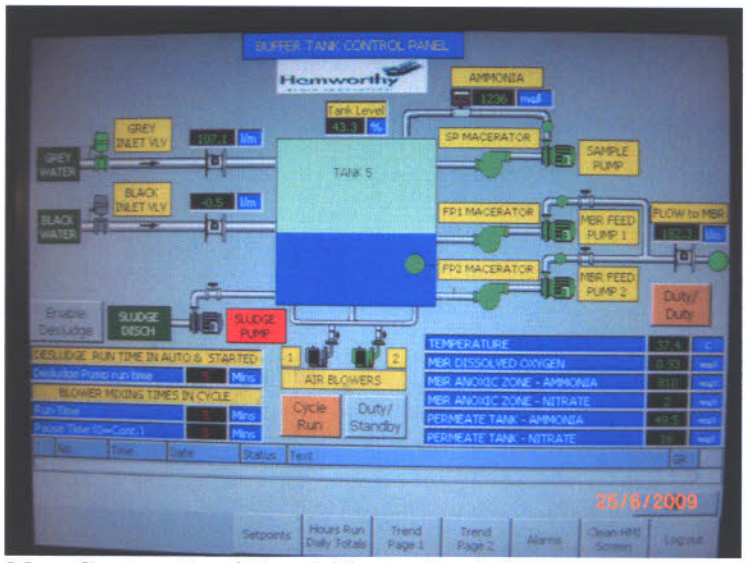
Impact of high flow

During the trial, the MBR No. 3 had increased treatment capacity due to the maintenance of another MBR. The results of such increased flow showed significant impact to ammonia as shown in the graph below.



Graph 5. Impact of increased flow to nitrification performance

In the next few months, Hamworthy will provide Princess Cruises with another progress report. This next update will present findings of nitrification efficiency under a lower ammonia concentration load in the wastewater feed. This will be achieved by increasing the grey to black water mixing ratio. Princess Cruises has also contracted Novatec/Analytica to perform additional ship sampling and laboratory analysis. The next report will include lab results that will be an important part of the trial conclusions.



New System Feed Panel illustrating influent into System

Though it is still early to make certain, the next report will likely conclude that by separating black and grey water treatment, the treated grey water may meet the interim limits, and be close to the long-term ammonia limit.

Sincerely,

George Wright
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